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A Study on Cooling Rate with Blade and Sound Fire Extinguisher

Bong-Young Kim[1]

[1]Department of Information and telecommunication Engineering
Soong-sil University, Seoul, Korea
[1]Orcid Id : 0000-0002-3553-039X

Myung-Jin Bae[2]*

[2]Department of Information and telecommunication Engineering
Soong-sil University, Seoul, Korea
[2]Orcid Id : 0000-0002-7585-0400

*(*Corresponding author: Myung-Jin Bae, Professor.)*

ABSTRACT

Since the Industrial Revolution, human civilization has developed rapidly and the buildings have become skyscrapered and their interior has become very complicated. A new conflagration suppression method is needed to suppress or prevent conflagration in various environments due to the change of fire fighting environment. Sound Fire Extinguisher, which is actively studied at Sori Sound Engineering Research Institute (SSERI), is a new type of extinguishment facility that can be used for suppression and prevention of conflagration in various environments. Sound Fire Extinguisher uses acoustic lens to minimize the attenuation of sound energy and transfer energy to the target point. It can prevent conflagration by lowering ambient temperature even before conflagration. In this study, we experimented to see if the Sound Fire Extinguisher could prevent conflagration by lowering the ambient temperature. Experimental results show that when the Sound Fire Extinguisher sound component of the same wind speed is supplied, the heated tableware is cooled by 10 ~ 20% faster than the wind speed of 2m/s. These results show that the Sound Fire Extinguisher can be used to prevent conflagration, since the sound component of the Sound Fire Extinguisher itself promotes the surrounding thermal dissipation to cool quickly.

Keywords: Conflagration, Sound Fire Extinguisher, Acoustic Lens, Sound Component, Cooling

I. INTRODUCTION

Human civilization has developed rapidly since Industrial Revolution. With the development of human civilization, buildings and their internal structures became skyscrapered and complicated. The conflagration suppression method should also be changed due to the changed fire fighting environment. Conventional conflagration suppression methods are mostly spraying a large amount of water directly to the conflagration field to lower the temperature or spray the extinguishing agent to block oxygen. However, this method is a countermeasure that can be taken when conflagration has already occurred and is causing damage. In addition, the spraying of water or extinguishing agent alone will destroy the information telecommunication infrastructure and other equipment. For these reasons, conflagration suppression method with suppressive function or preventive function is required in various environments [1-2].

Sori Sound Engineering Research Institute (SSERI) is actively researching Sound Fire Extinguisher which can be used to suppress and prevent conflagration in various environments. The Sound Fire Extinguisher was first introduced in the US Defense Advanced Research Projects Agency (DARPA), where low frequency sounds resonate with flame molecules to affect extinguish, and furthermore SSERI is being developed for use in real fire fighting environments. Sound Fire Extinguisher suppresses conflagration by using a sound component that is not water or extinguishing agent, so it can minimize the damage of various equipment such as information telecommunication infrastructure and can be fully used as a preventive even before conflagration occurs. In particular, by applying an acoustic lens to the Sound Fire Extinguisher, the sound component is collimated to one side to eradicate it, thereby enhancing the extinguishable efficiency and maximizing various effects of the sound. Figure 1 is a portable Sound Fire Extinguisher under study at SSERI [3-7].

Fig 1. Portable Sound Fire Extinguisher

In this paper, we compared the cooling rate of the blade and Sound Fire Extinguisher to check if the sound component of Sound Fire Extinguisher can prevent conflagration by lowering ambient temperature before conflagration occurs. In Chapter 2, the sound fire extinguisher sound component collimation using the acoustic lens is explained. In Chapter 3, the experiment and the result are discussed. Chapter 4 concludes.

II. SOUND FIRE EXTINGUISHER'S SOUND COMPONENT COLLIMATION BY ACOUSTIC LENS

Acoustic Lens: An acoustic lens is a device that focuses or collimates sound energy. In general, sound emits the same energy in all directions, so the propagated form becomes spherical. Therefore, when the propagation distance is doubled, the propagation area is quadrupled and the propagated energy is reduced to 1/4. An acoustic lens is placed on the path of sound propagation to focus sound energy. Sounds are refracted at the interface of different mediums like other types of waves. When an acoustic lens with radius of curvature R is installed in front of the oscillator, the distance F at which the sound is focused can be approximated as shown in equation (1). Figure 2 is a schematic of an acoustic lens [8-11].

$$R = F \cdot \frac{n-1}{n} \tag{1}$$

R : Radius of curvature of acoustic lens

F : Distance to focus

n : Sound velocity ratio between medium1(acoustic lens) and medium2

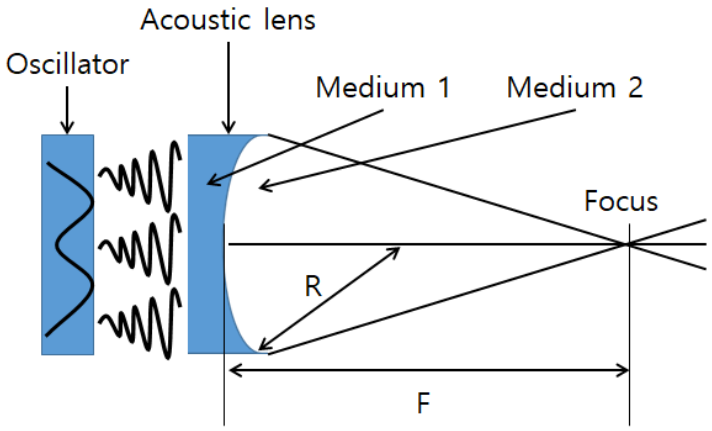

Fig 2. Schematic of Acoustic Lens

Sound Fire Extinguisher's Sound Component Collimation: The point where the sound energy is concentrated through the acoustic lens is called focus. When a sound source is placed at the focus of an acoustic lens, the sound wave passing through the lens becomes a plane wave that transfers energy to a certain area. Sound Fire Extinguisher uses a special acoustic lens to collimate a sound component so that it propagates as a plane wave. Thus, in the case of a Sound Fire Extinguisher, the sound passing through the acoustic lens minimizes attenuation and can transfer energy to the flame. Generally, in the sound field, the wind speed is not formed because the low density part and the high part of the medium particle repeatedly change and the wave is transmitted. However, Sound Fire Extinguisher uses acoustic lens to collimate the

sound energy, so the variation of medium particle density becomes very large and wind speed is formed. The portable Sound Fire Extinguisher used in the experiment has a wind speed of about 10m/s at a distance of 10cm [8-11].

III. EXPERIMENTS AND RESULTS

Experiments were carried out to measure the temperature change from 100 ℃ by heating stainless steel tableware. The experiment was conducted in three cases: first, the temperature change was measured with natural cooling; second, when the blade was blowing; and third, when the sound component of the Sound Fire Extinguisher was supplied. In order to compare the Blade and Sound Fire Extinguisher under the same conditions as possible, the distance between the blade and the stainless steel tableware is 50 cm, the distance between the sound fire extinguisher and the stainless tableware is 90 cm and the wind speed reaching the stainless tableware is 2 m/s, respectively. The temperature change of the stainless steel tableware was recorded with video using thermal imaging camera FLIROne and Galaxy Note 4. The temperature was measured at the same position inside the tableware for each experimental cycle. The experimental environment is shown in Figure 3.

Fig 3. Experiment Environment

At the time of the experiment, depending on the experimental environment such as the ambient temperature, it may affect the rate of cooling the stainless tableware. In addition, measurement errors may occur depending on the location of the thermal imaging camera. Therefore, in order to compare the measured results under the same environmental conditions for each experimental cycle, all the experimental tools were fixed so that the temperature measurement positions could be the same. Also, in each experimental cycle, one experimental cycle was completed within 30 minutes to simulate the ambient temperature. The comparison between different experimental cycles is meaningless because the experimental environment including the ambient

temperature is different and the temperature measurement position is slightly different. However, in the same experimental cycle, it can be said that the result is comparative measurement under the same condition. The actual experiment scene and temperature measurement screen are shown in Figure 4.

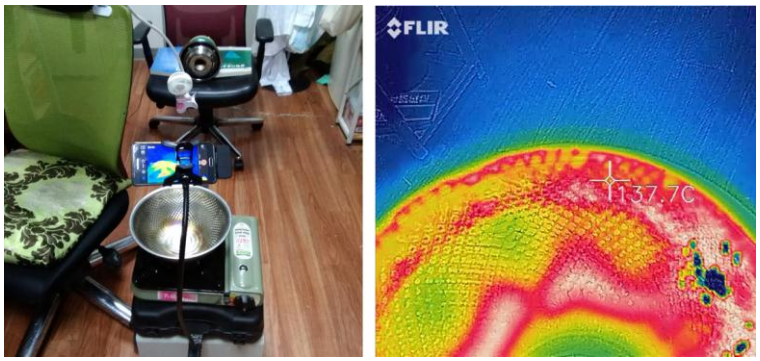

Fig 4. Experiment scene and thermal image recording screen

Figure 5 is a graph of the experimental results of Figure 4. Figure 5 shows the comparison of measured temperature changes when natural cooling, wind of the blade are supplied, and sound components of the Sound Fire Extinguisher are supplied. In Figure 5, it took 82 seconds to cool the stainless tableware by natural cooling from 100 °C to 50 °C, and it took 33 seconds when the wind of the blade was supplied. However, when the sound component of Sound Fire Extinguisher was supplied, it took 22 seconds and the temperature decreased more rapidly.

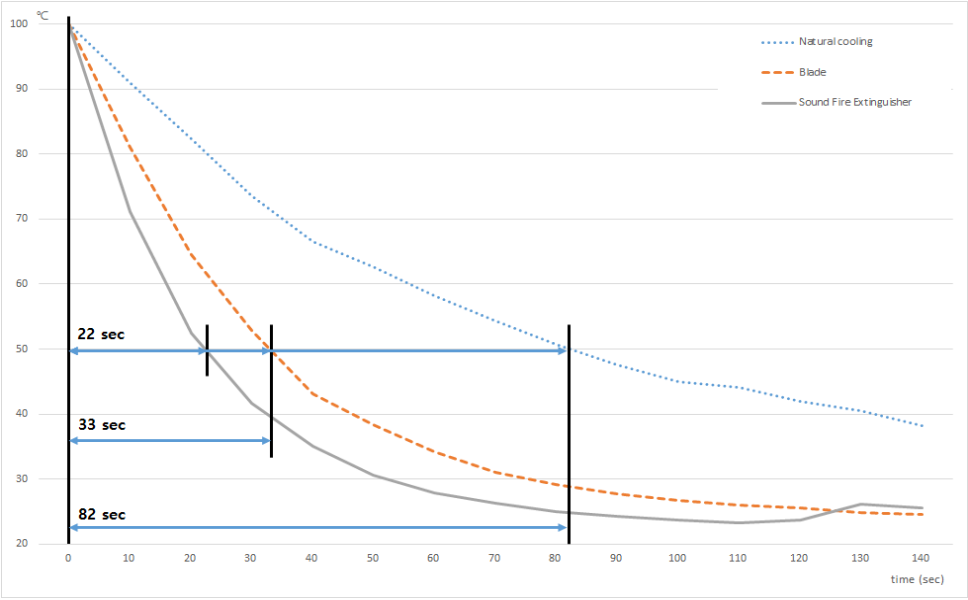

Fig 5. Temperature change measurement result

The experiment as shown in Figure 4 and Figure 5 was performed 8 times in total. Table 1 shows the results of measuring the cooling time of the stainless tableware for each experimental cycle. The results of Table 1 show that the supply of wind of the blade to heated tableware was cooled more rapidly than that of natural cooling. However, if the sound component of the Sound Fire Extinguisher is supplied to the heated tableware, it will cool more quickly than when the wind of the blade are supplied. Especially, all of the eight experiments showed that the cooling effect of the Sound Fire Extinguisher's sound components was the best. In addition, the results of the whole experiment showed that the sound component of the Sound Fire Extinguisher was cooled 10 ~ 20% faster than when the wind of the blade were supplied.

Table (1) Experimental results (measurement of the time required for temperature reduction)

Experimental cycle		Temperature reduction time (sec)				
		100℃→ 90℃	100℃→ 80℃	100℃→ 70℃	100℃→ 60℃	100℃→ 50℃
1’st	Natural cooling	8	19	33	47	71
	Blade	4	8	13	19	28
	Sound Fire Extinguisher	4	7	12	18	26
2’nd	Natural cooling	11	23	35	56	82
	Blade	5	10	17	24	33
	Sound Fire Extinguisher	3	7	11	16	22
3’rd	Natural cooling	10	23	37	56	80
	Blade	4	8	13	20	30
	Sound Fire Extinguisher	4	8	13	19	27
4’th	Natural cooling	11	23	38	57	83
	Blade	5	9	15	22	33
	Sound Fire Extinguisher	4	8	13	19	28
5’th	Natural cooling	11	24	40	57	83
	Blade	4	9	15	22	32
	Sound Fire Extinguisher	4	8	13	19	27
6’th	Natural cooling	8	21	34	50	77
	Blade	5	10	16	23	35
	Sound Fire Extinguisher	4	8	12	19	26
7’th	Natural cooling	9	20	30	47	78
	Blade	6	12	17	24	33
	Sound Fire Extinguisher	5	9	15	23	34
8’th	Natural cooling	10	20	33	50	77
	Blade	5	9	15	22	32
	Sound Fire Extinguisher	4	8	13	20	29
Average	Natural cooling	10	22	35	53	79
	Blade	5	9	15	22	32
	Sound Fire Extinguisher	4	8	13	19	27

IV. CONCLUSION

Conventional conflagration suppression method is mostly spraying water or extinguishing agent in conflagration field. However, since the building is skyscrapered and its interior is also very complicated, a new method of conflagration suppression method applicable to various environments is needed. Sound Fire Extinguisher, which is being actively studied at SSERI, is a new extinguishing facility that can be applied to various fire fighting fields.

In this study, we tried to confirm the cooling effect of Sound Fire Extinguisher by comparing with blade. As a result of experiment that the wind speed reaching to the stainless tableware is 2m/s, the Sound Fire Extinguisher's sound component was found to cool the stainless tableware by 10 to 20% faster than when the wind of the blade were supplied. The wind of the blade simply lowers the heat by moving the air around the tableware. On the other hand, the sound component of the Sound Fire Extinguisher can be said to cool more quickly because it dramatically changes the air density around the tableware to promote heat diffusion. These results show that Sound Fire Extinguisher has a high cooling effect even at the same wind speed and can be used for conflagration suppression as well as conflagration prevention. In addition, the Sound Energy Extinguisher's special acoustic lens collimates the sound energy, so we can see that the sound energy is well transmitted to the target point.

Sound Fire Extinguisher will be able to produce various effects depending on the sound component. Future applications of Sound Fire Extinguisher for various purposes have been studied, and we hope to be able to use Sound Fire Extinguisher in various applications in fire fighting field.

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